

# **ADVANCES IN DISPLAY TECHNOLOGIES**

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# ATTRIBUTES

**HIGH RESOLUTION  
HIGH BRIGHTNESS  
LARGE VIEWING ANGLE  
HIGH WRITING SPEEDS  
LARGE COLOUR GAMUT  
HIGH CONTRAST  
LESS WEIGHT AND SIZE  
LOW POWER CONSUMPTION  
LOW COST**

# TECHNOLOGIES

- ◆ CATHODE RAY TUBE (CRT)
- ◆ VACUUM FLOURECENT DISPLAY (VFD)
- ◆ FIELD EMISSION DISPLAY (FED)
- ◆ LIQUID CRYSTAL DISPLAY (LCD)
- ◆ PLASMA DISPLAY PANEL (PDP)
- ◆ ELECTROLUMINESCENT DISPLAY (EL)
- ◆ ORGANIC LIGHT EMITTING DIODE (OLED)

# CRT

**100 YEAR OLD WORKHORSE**  
**CATHODOLUMINISCENT**  
**BEAM SCAN DEVICE**  
**LARGE VIEWING ANGLE**  
**HIGH BRIGHTNESS**  
**HIGH RESOLUTION**  
**GOOD COLOUR GAMUT**  
**BEST PERFORMANCE TO COST**  
**BULKY HEAVY**  
**UNIMPLEMENTABLE IN LARGE SIZES**  
**OBSOLESCENCE**  
**STILL ENJOYS 70% MARKET**

# VFD



- ◆ Earliest Flat technology
- ◆ Low Cost
- ◆ Good Luminance
- ◆ Excellent Viewing Angle
- ◆ Long Life
- ◆ Matrix Addressing
- ◆ Wire Emitters
- ◆ Cathodoluminescent
- ◆ Mechanical Complexity
- ◆ Low Resolution
- ◆ High Filament Power

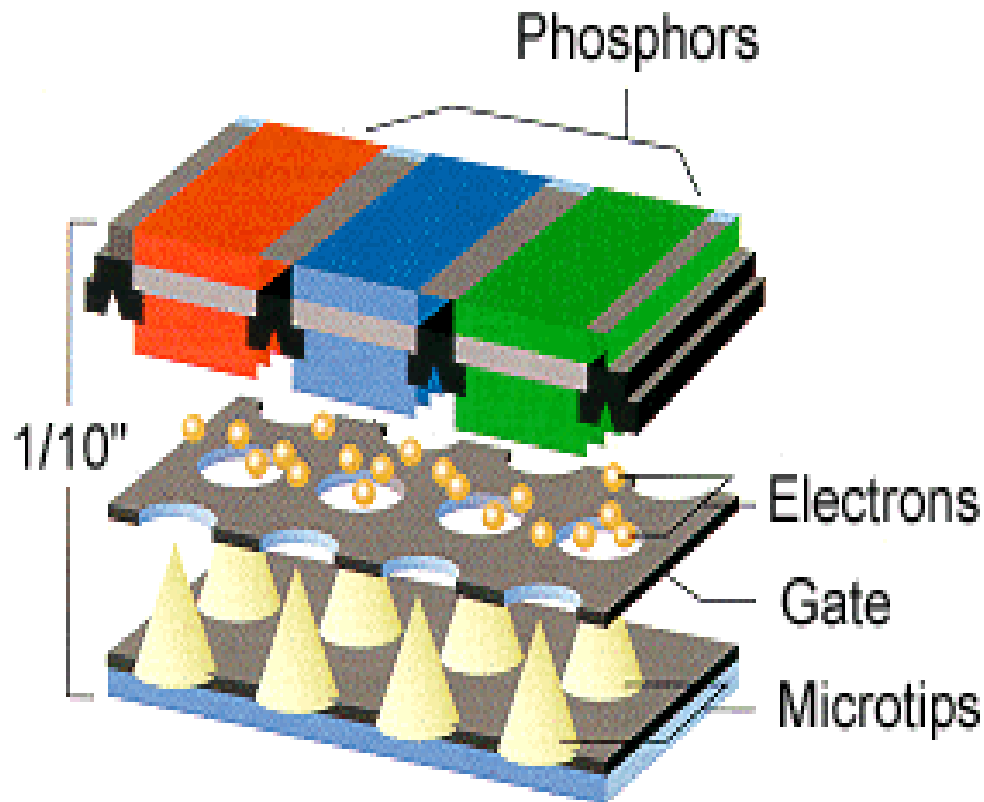
# FED

- ◆ MATRIX DISPLAY
- ◆ LARGE VIEWING ANGLE
- ◆ HIGH BRIGHTNESS,HIGH RESOLUTION
- ◆ EXCELLENT COLOUR GAMUT
- ◆ TECHNOLOGY NOT MATURE

# FIELD EMISSION

- ◆ SPINDT STRUCTURE
- ◆ MIM
- ◆ SURFACE EMISSION
- ◆ CARBON DIAMOND LIKE FILMS
- ◆ CARBON NANOTUBES

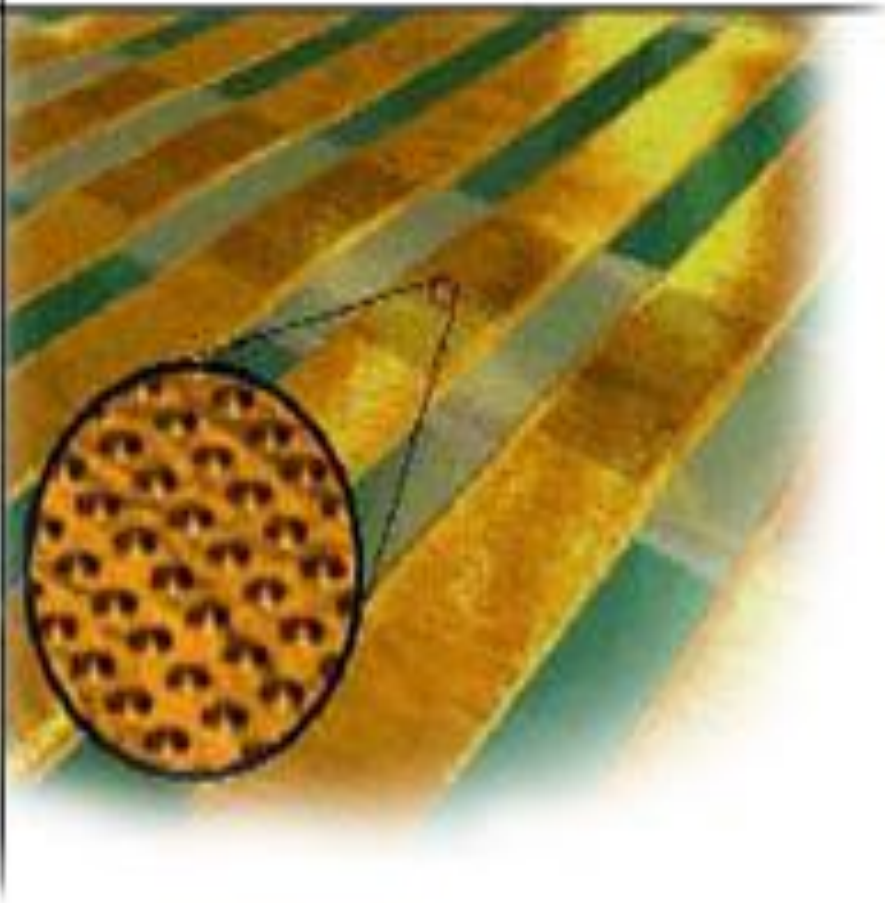
# FED Principles



- ❖ Field emission displays, electrons coming from millions of tiny microtips pass through gates and light up pixels on a screen.
- ❖ This principle is similar to that of cathode-ray tubes in television sets.
- ❖ The difference: Instead of just one "gun" spraying electrons against the inside of the screen's face, there are as many as 500 million of them (microtips).

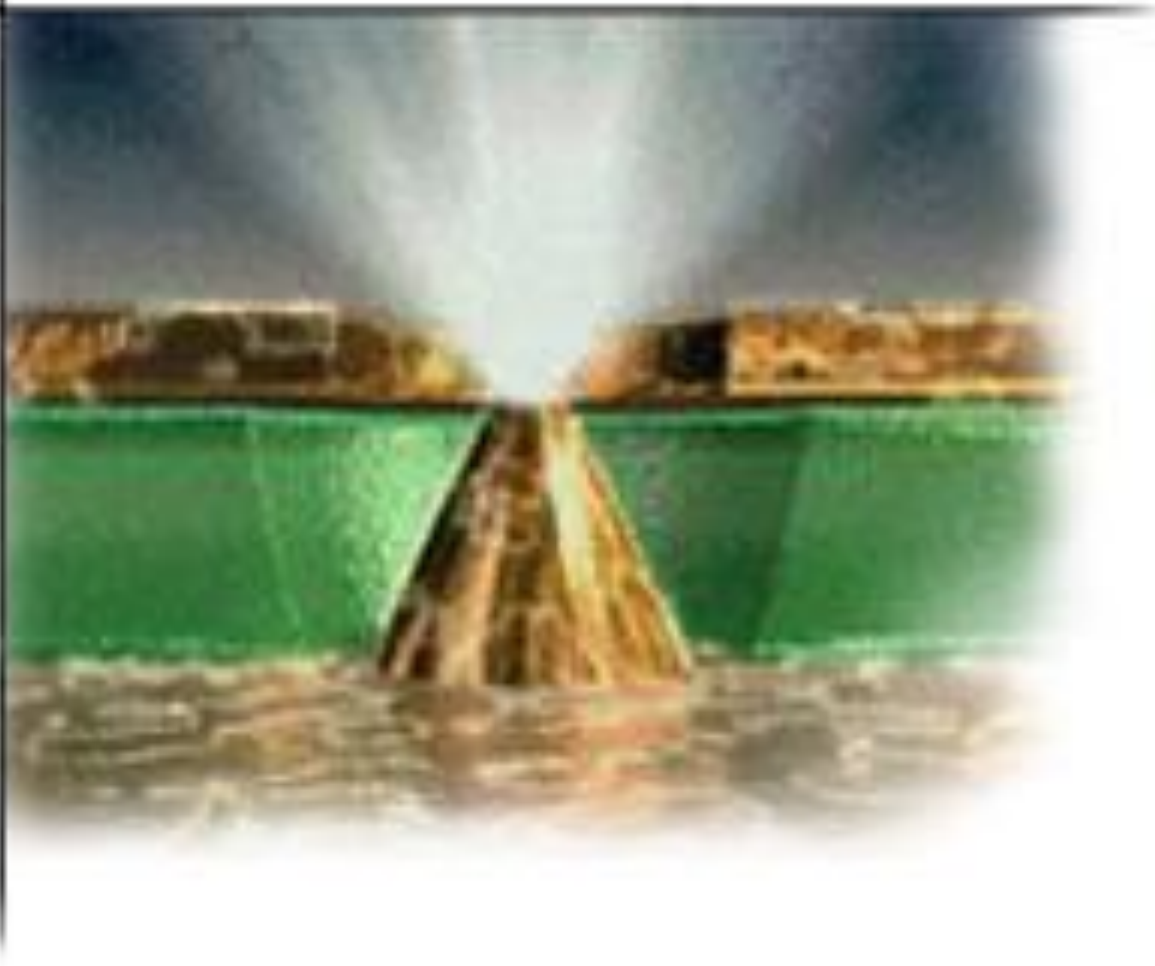


# Cathode



- ❖ The cathode/backplate is a matrix of row and column traces.
- ❖ Each crossover lays the foundation for an addressable cathode emitters.
- ❖ Each crossover has up to 4,500 emitters, 150 nm in diameter.
- ❖ This emitter density assures a high quality image through manufacturing redundancy, and long-life through low operational stress.

# Emission



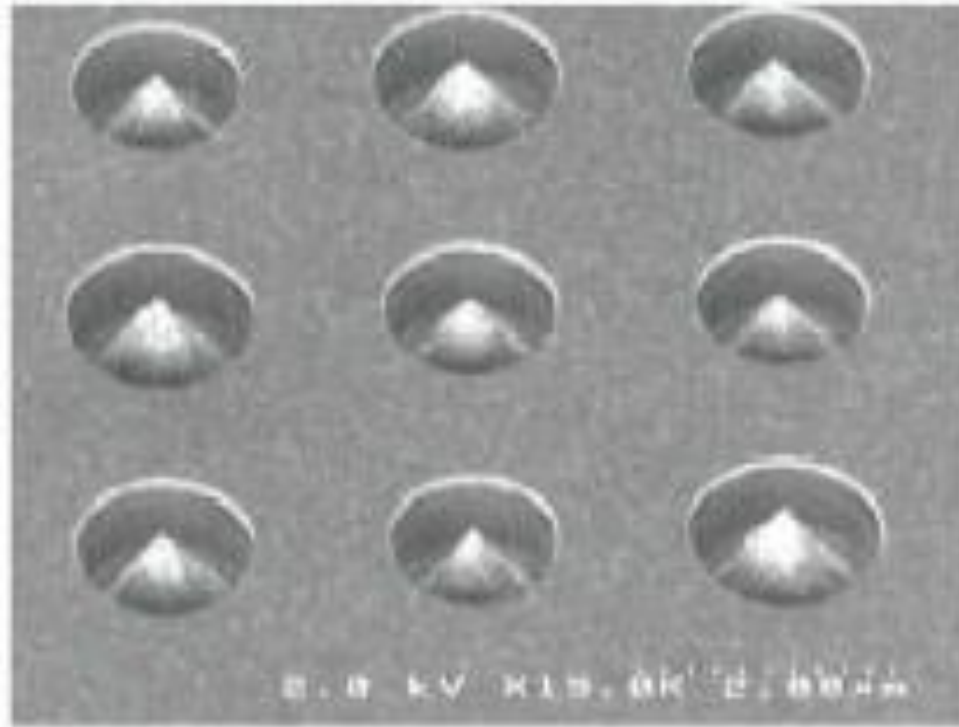
Emitters generate electrons when a small voltage is applied to both row (base layer) and column (top layer).

# Pixels



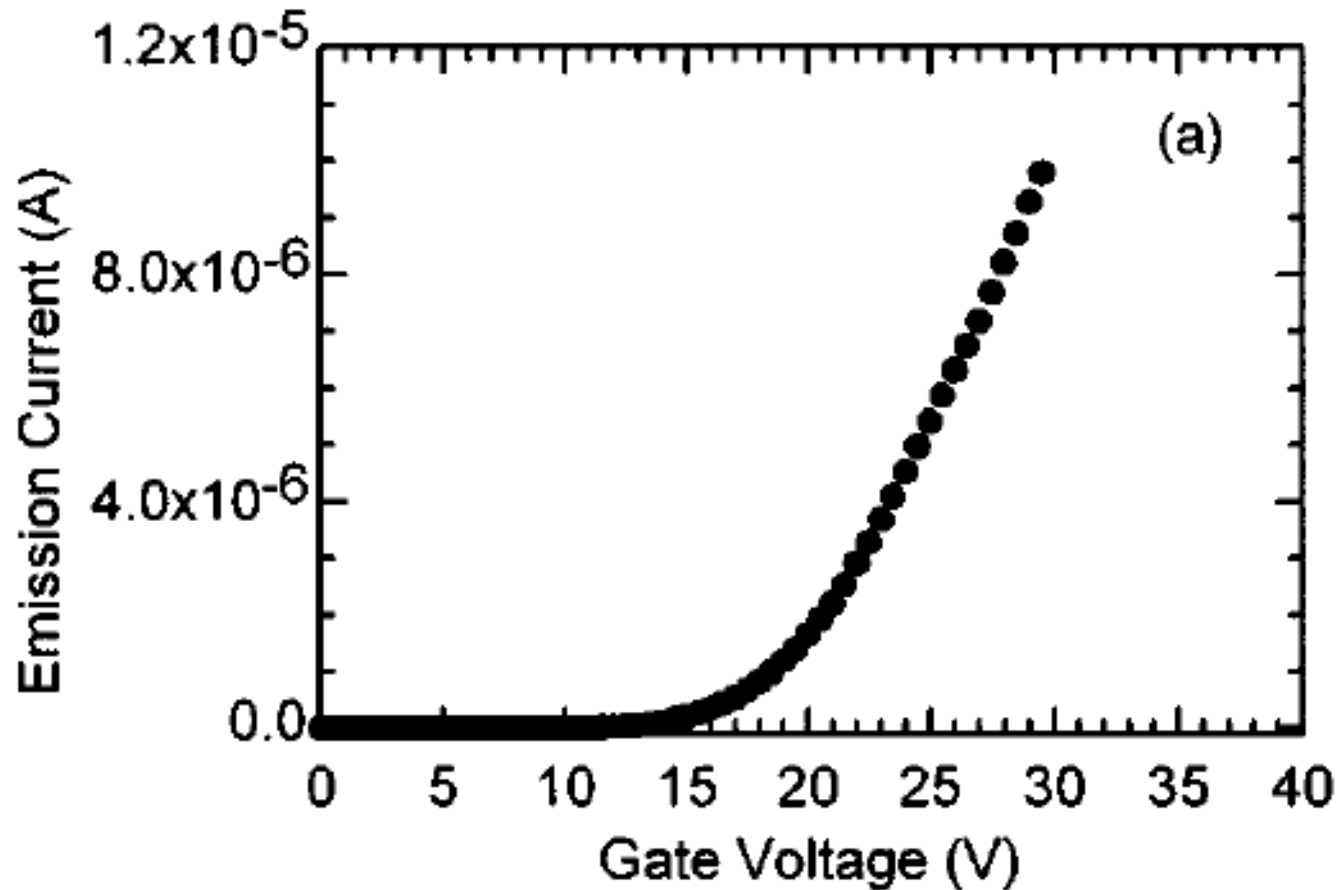
Faceplate picture elements (pixels) are formed by depositing and patterning a black matrix, standard red, green, and blue TV phosphors and a thin aluminum layer to reflect colored light forward to the viewer.

# Metal Tips



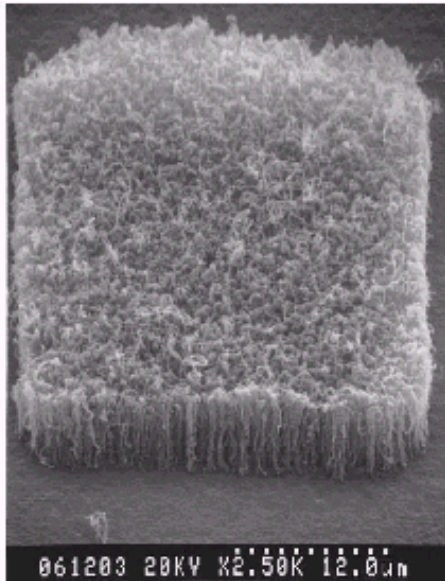
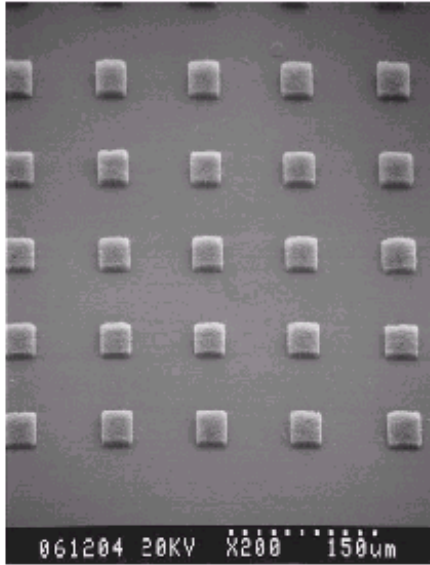
Display field emission array delivering  
 $60\text{mA}/\text{cm}^2$  at 114V gate voltage

# I-V of Metal Tip



Typical field emission characteristics of the FEA pixel with an area of 240 mm x 240 mm containing  $1.4 \times 10^6$  tips:

# Carbon Nanotube



Characterised by

- Superior mechanical strength (bending modulus 1 TPa)
- Low weight
- Good heat conductance
- Ability to emit a cold electron at relatively low voltages due to high aspect ratios ( $10^2$ – $10^4$ ) and nanometer size tips (1 – 50 nm).



# FED advantages

Inherently high luminous efficiency

- ◆ No Response Time issues
- ◆ CRT-like Colour Gamut
- ◆ Lower Power Consumption
  - Cold Cathode Emission
  - Distance between cathode and screen ~0.2–5mm
- ◆ Flat Panel Technology
  - Matrix Addressed – No DY
- ◆ Capital investment for manufacturing VLS TV with printable CNT FEDs - 1/10<sup>th</sup> of LCD
- ◆ Cost advantage over LCD could be 40%

Technology	Luminous Efficiency (Lm/W)
CRT (at 30KV)	3
PDP	0.8
LCD	3
OLED / PLED	5
FED at 8 KV	7

# FED Technology Roadblocks

## ◆ Spindt type FED

- Yield problems – Tip wear off, high vacuum
- High cost of submicron technology for Spindt type emitters
- High Voltage Breakdown due to electron bombardment and spacer charging
- Phosphor decay in case anode is at low voltage to counter the above problem
- Backscatter from anodes at high anode voltages leading to cross talk



# FED – Technology Options

## ◆ Spindt Type Emitters

- Oldest, Expensive and Yield problems

## ◆ Carbon Nanotube Emitters (Max R&D funds)

- Japanese funding lot of research for display application
- Has problems with Short range uniformity
- Potential of low cost printing for manufacture

## ◆ SED (Surface-Conduction Electron-Emitter Display)

- Does not have emitting tips, uses electron tunneling
- Being pursued by Toshiba – Canon (IPR bought from Candescent) for commercialisation (50" prototype by 2005)

# EL

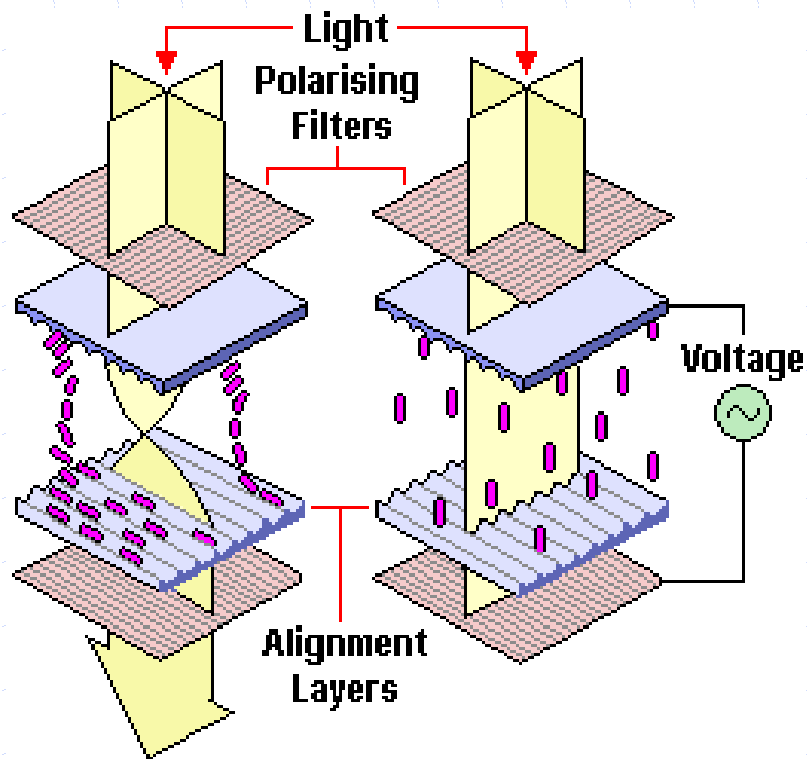
- ◆ The structure consists of two thin layers of dielectric with phosphor sandwiched between them. A thin Al layer on the top and thin ITO layer on the bottom completes EL. When voltage of order of 200V is applied the resultant high electric field (1MV/cm) tunnels electrons through dielectric on to phosphor. The high energy of electrons impact the colour centres to emit visible light.
- ◆ High brightness, high resolution,
- ◆ Blue phosphor improvement required
- ◆ High voltage switching
- ◆ High purity materials
- ◆ Small sizes
- ◆ Expensive

# LCD



- ◆ Most mature flat panel technology
- ◆ Major share of FPD market
- ◆ Poor intrinsic viewing angle
- ◆ Requires backlight
- ◆ Inefficient
- ◆ Slow
- ◆ Effected by Temperature and sunlight

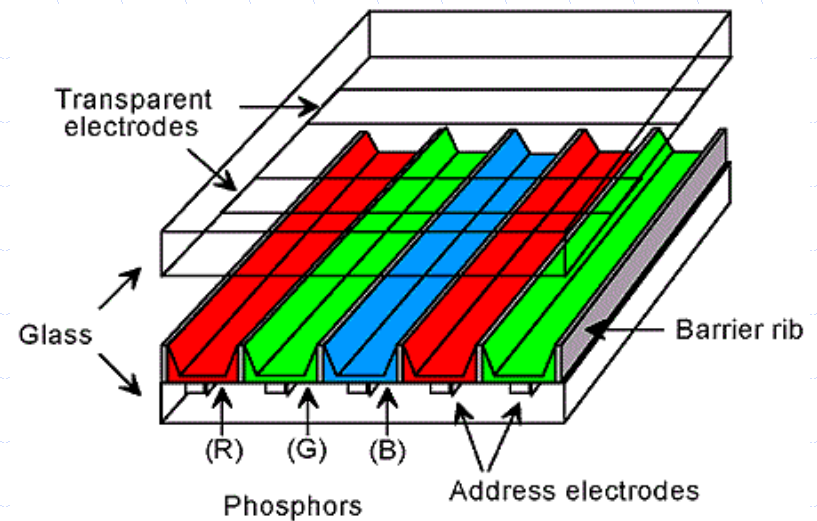
# LCD



- ◆ There are many modes operation
- ◆ **B VA RT**
- ◆ TN 90 deg twist **H P S**
- ◆ STN 270 deg twist **H P S**
- ◆ IPS in plane switching **P VG P**
- ◆ MVA multidomain vertical alignment **P G G**
- ◆ OCB optically self compensated birefringence **G G VG**

# PDP

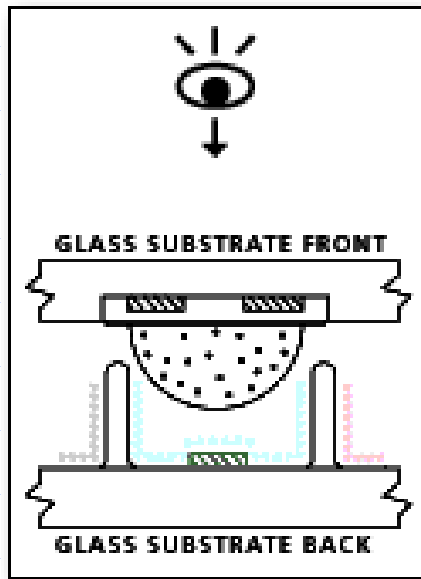
- ◆ Large Displays >32"
- ◆ High Resolution
- ◆ High Brightness
- ◆ Good Contrast
- ◆ Good Colour gamut
- ◆ Large viewing angle
- ◆ High Speed
- ◆ **Presently High Cost**



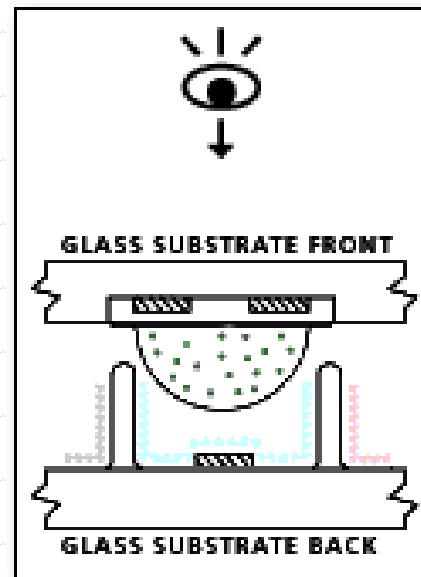
# PLASMACO 60" AC PDP



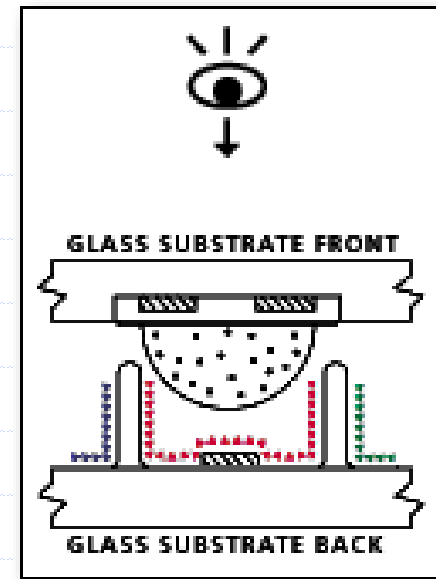
# PDP Working



Address electrode causes gas to change to plasma state.

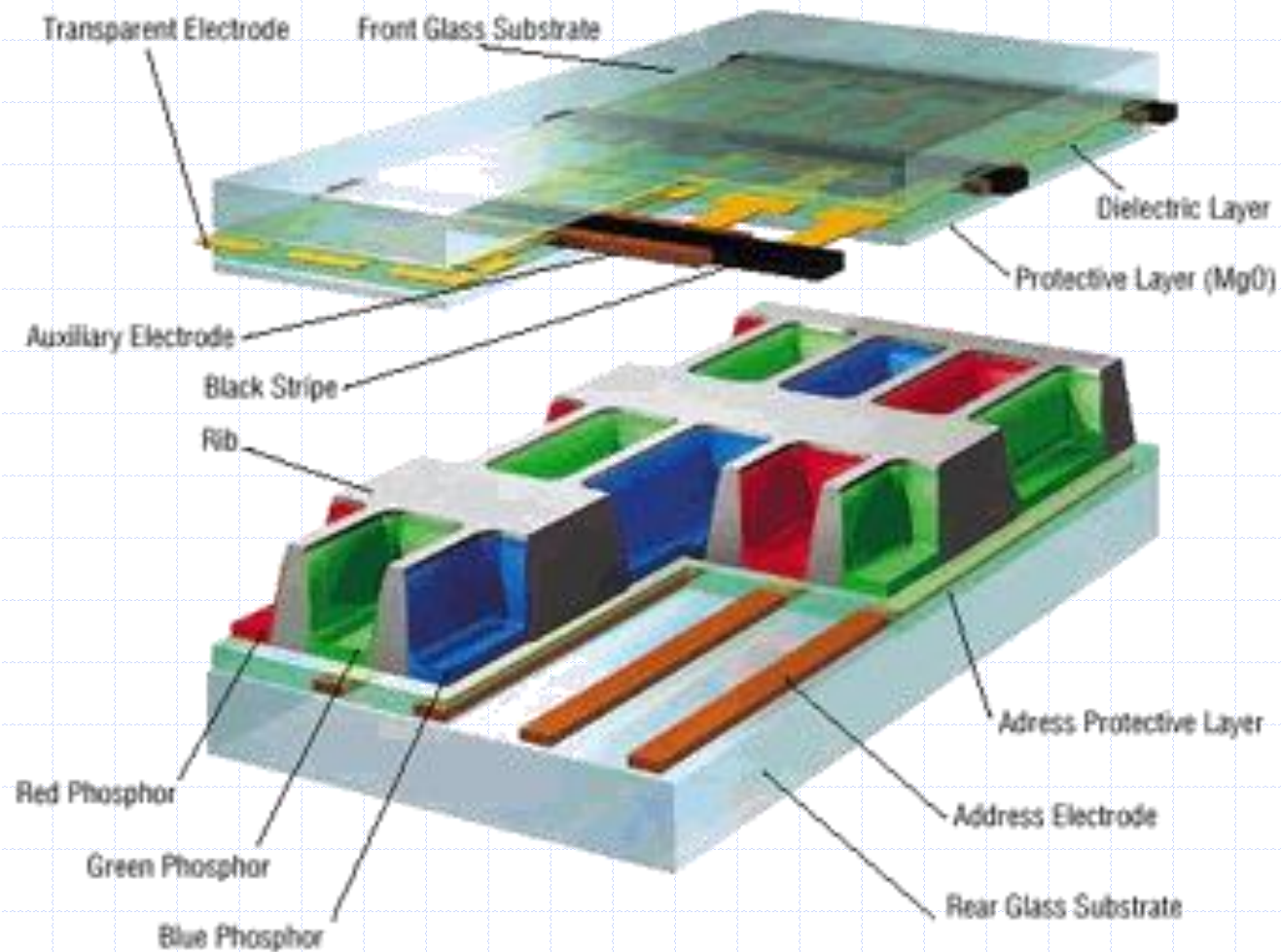


The plasma emits UV in discharge region which impinges on the phosphor



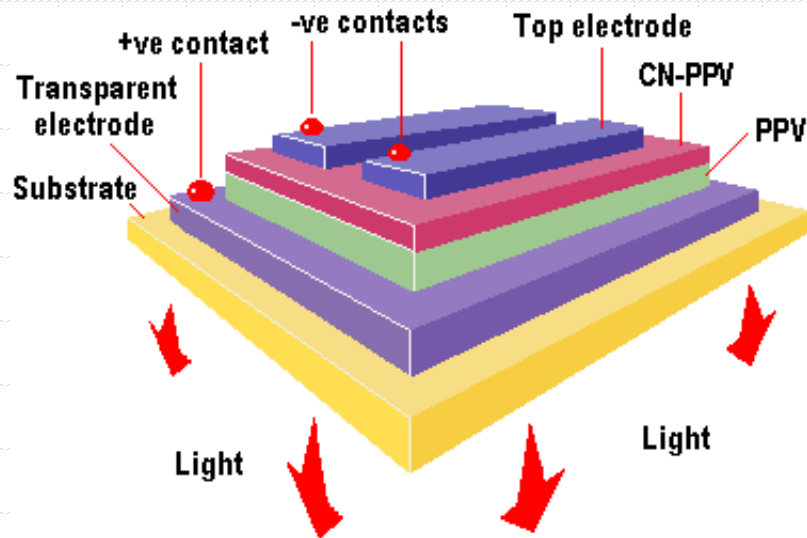
Reaction causes each subpixel to produce red, green, and blue light.

# Structure of a PDP





# OLED

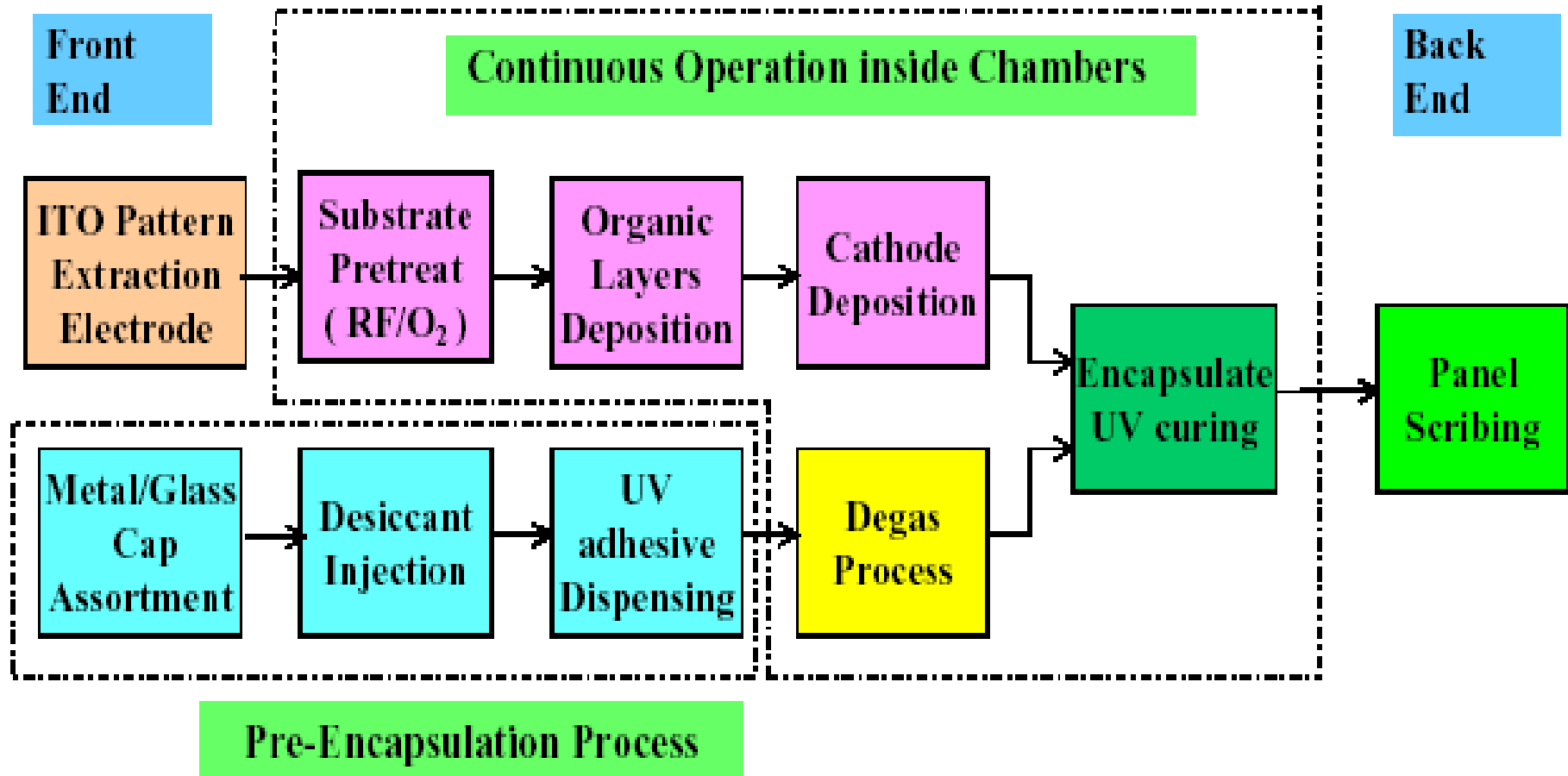


- ◆ Most promising technology
- ◆ Already in small sizes
- ◆ No inherent size limit
- ◆ Conformal displays
- ◆ Large viewing angle
- ◆ High resolution
- ◆ High Speed
- ◆ Good colour gamut
- ◆ Lifetime issues to be solved
- ◆ Great threat to LCD 2008?

# OLED advantages

- ◆ Colour Gamut comparable to CRT, with potential to get better – Striking visual appeal
- ◆ Thinner – No backlight
- ◆ Less Expensive than LCD due to lesser components
  - White + Color Filter route takes away some of this advantage
- ◆ Potential for printing in manufacturing.
- ◆ **Flexible and Conformal Displays**

# OLED Process



# OLED Roadblocks

## ◆ Materials

- Small molecule lifetimes still not OK for TV applications, although robust for mobile phones
- Polymers struggling with material stability

## ◆ Manufacturing

- UHV process not easily scalable to larger Mother Glass. Currently, manufacturing restricted to 370 x 470mm
- Printing (Polymers) still in R&D stage

## ◆ Active Matrix Back plane

- Incompatible with the existing a:Si technology
- LTPS technology (considered suitable for current driven devices) suffers from uniformity problems and restricted to displays < 8"

# PROJECTION DISPLAY

## Classification:

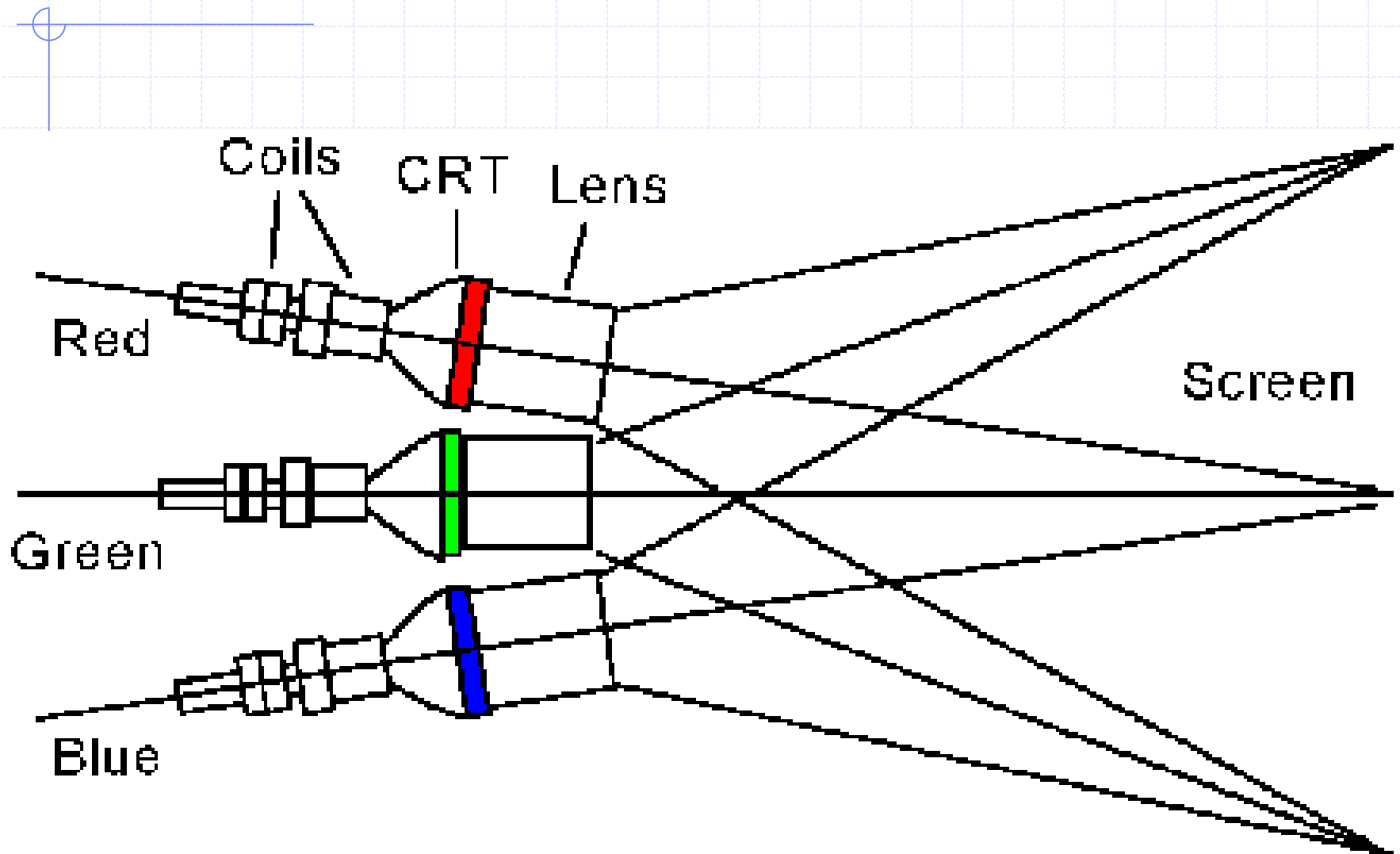
Front projection

Rear projection

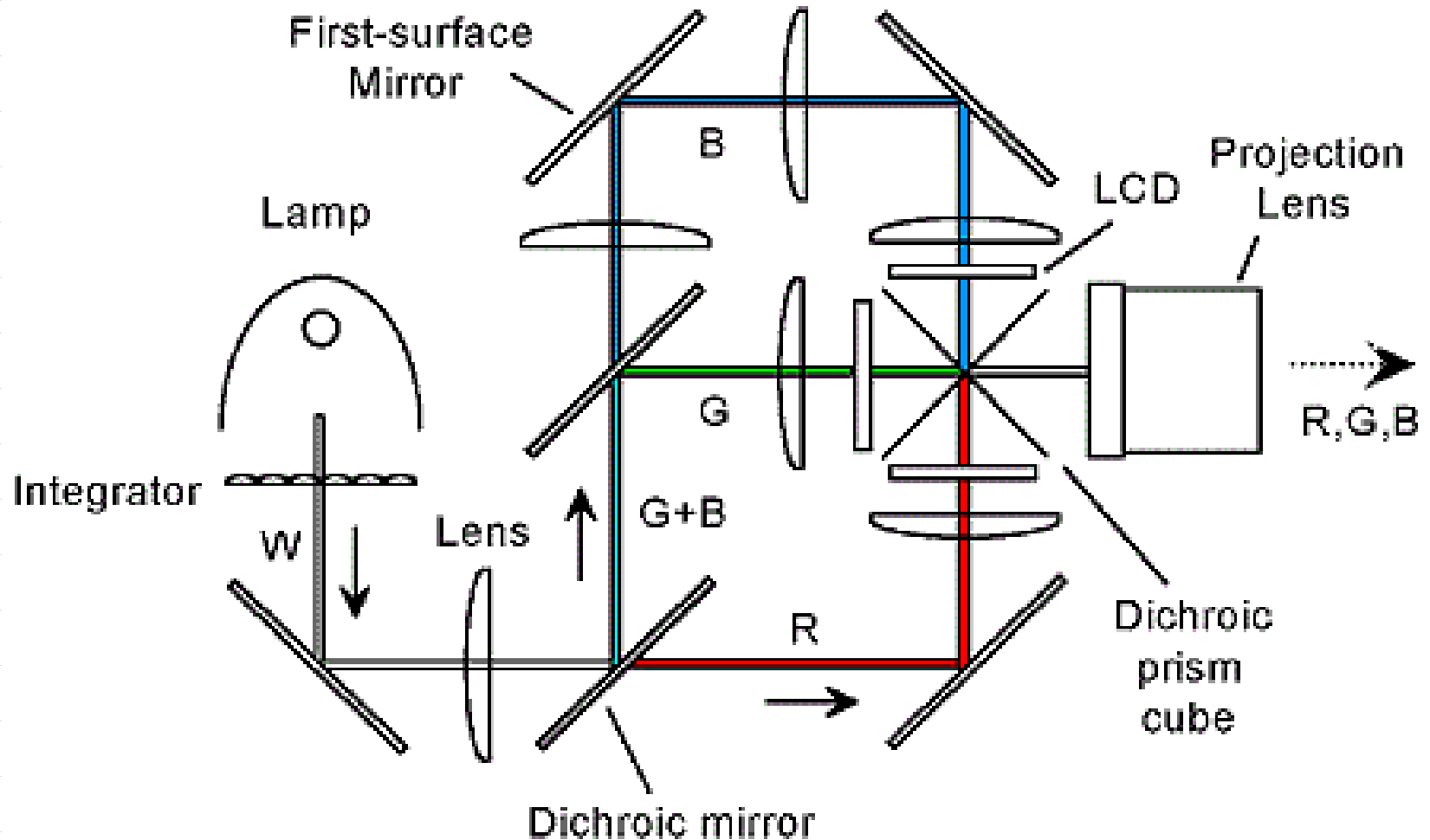
## Technology:

CRT	-	Emissive
LCD	-	Transmissive / Reflective
DLP/DMD	-	Reflective
GLV	-	Diffraction
LCOS	-	Reflective

# Rear Projection CRT

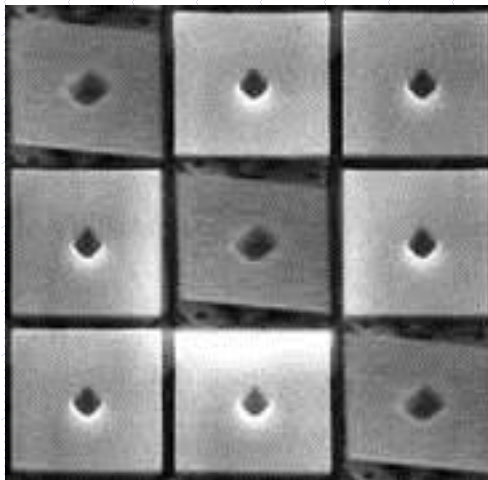


# Rear Projection LCD / LCoS



# Digital Mirror Device

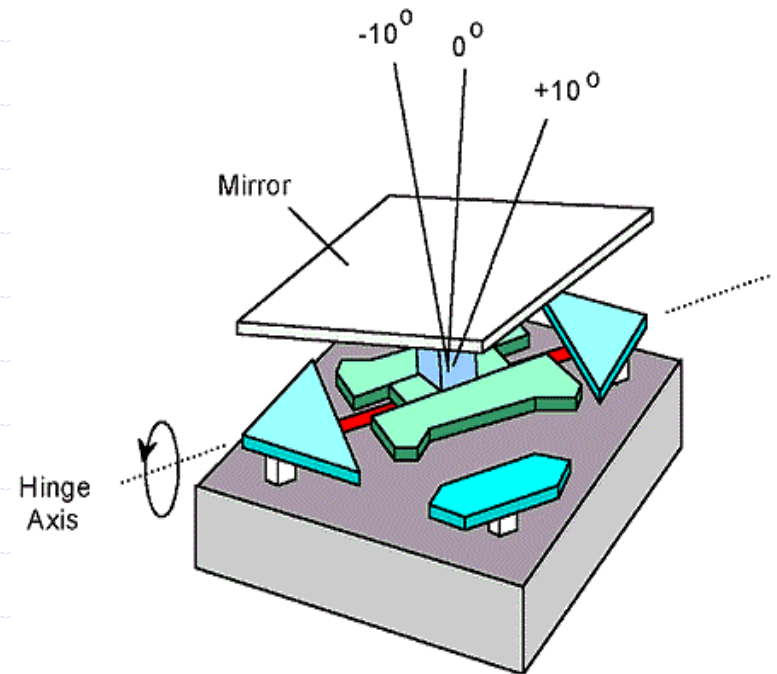
- The DMD is an array of several lakhs of aluminium mirrors, each of which acts as a light switch.
- It is a MEMS device.





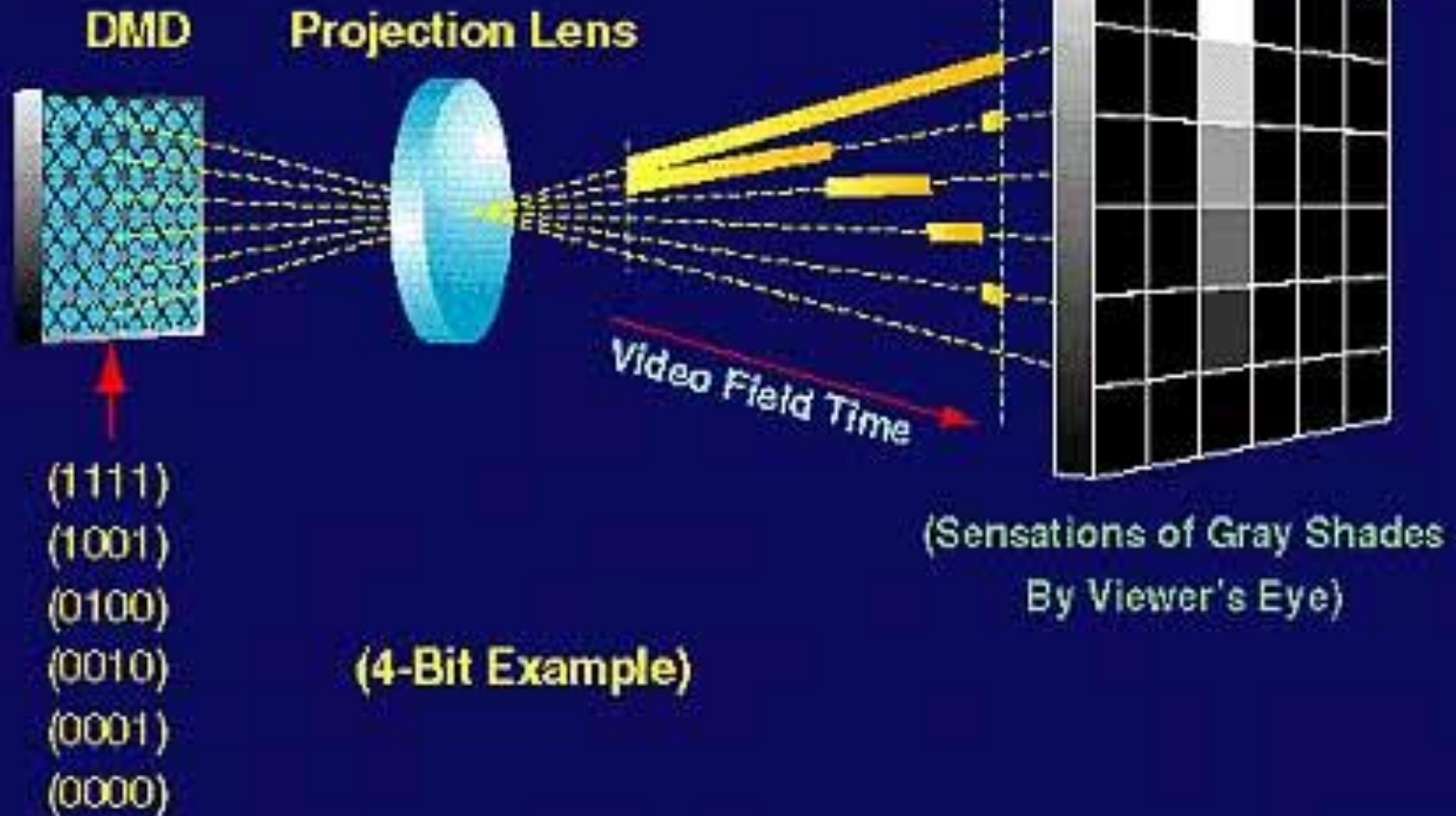
Each mirror can rotate in one of two directions:  
+ 10 degrees or -10 degrees.

+10 degrees is ON state.  
-10 degrees is OFF state.



# Digital Grey scale control

(Note: for clarity, only central column is addressed and no light source is shown)



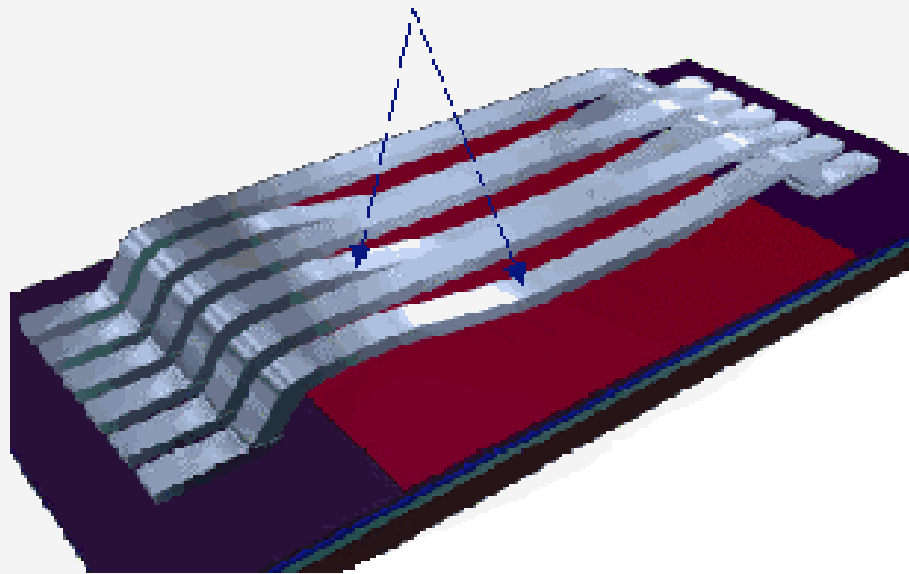
# Grating Light Valve

- ◆ Originally developed and patented by Professor David Bloom and his students at Stanford University.
- ◆ Further work done by Silicon Light Machines.
- ◆ GLV technology acquired by SONY for applications in display devices => Expect rapid growth.
- ◆ In the high-end display market (simulation, planetarium) Silicon Light Machines is partnered with Evans & Sutherland.
- ◆ Silicon Light Machines acquired by Cypress Semiconductor Corporation - GLV technology for optical communication.

GLV device -- parallel rows of reflective ribbons.

Alternate rows of ribbons can be pulled down to create a diffraction grating.

Alternate ribbons are deflected to create a square-well diffraction grating



# DISPLAY CATEGORISATION

- **Microdisplays ( < 1" diagonal):** These displays are too small to be seen in direct view and need some kind of optical magnification. However they are required to have high resolution and high brightness. Important examples are camera viewfinders and light valves for projection systems
- **Small ( 1" - 8"):** These are used in handheld devices such as digital cameras, PDA, cell and videophones as well as many instruments. These displays dominate in volumes. They are price sensitive and hence manufacturing methods and technologies are chosen for cost reduction.
- **Medium ( 8" - 30")** These account for the great majority of the industry revenue. Two critical applications are desktop and notebook personal computers. Television is another major consumer product in this range but FPD still does not have any significant presence yet.
- **Large ( > 30")** These are for high end television , home theatre, public announcements, advertising etc. Volumes are small but value is high.

# TECHNOLOGY ATTRIBUTES

Attribute	PMLCD	AMLCD	LCOS	PDP	FED	DLP	OLED
<b>Size</b>	< 15"	<15"	< 1"	>30"	<15"	> 60"	No limit
<b>Brightness nits</b>	< 100	<100	<100	<500	<500	<500	>10000
<b>Resolution</b>	Medium	High	High	High	High	Medium	High
<b>Inherent VA</b>	Small	Small	Medium	Large	Large	Large	Large
<b>Efficiency lm/w</b>	6	6	-	1	5	6	50
<b>Colour gamut</b>	Good	Good	Good	Good	Good	Good	Good
<b>Manuf. cost</b>	Medium	V.High	High	Medium	Medium	High	Low
<b>Cost pid</b>	1	5	5	1	2	3	<1
<b>Market presence</b>	Established		Establish	Established	Entering	?	
Established	In 2 years						

# TECHNOLOGY vs APPLICATION

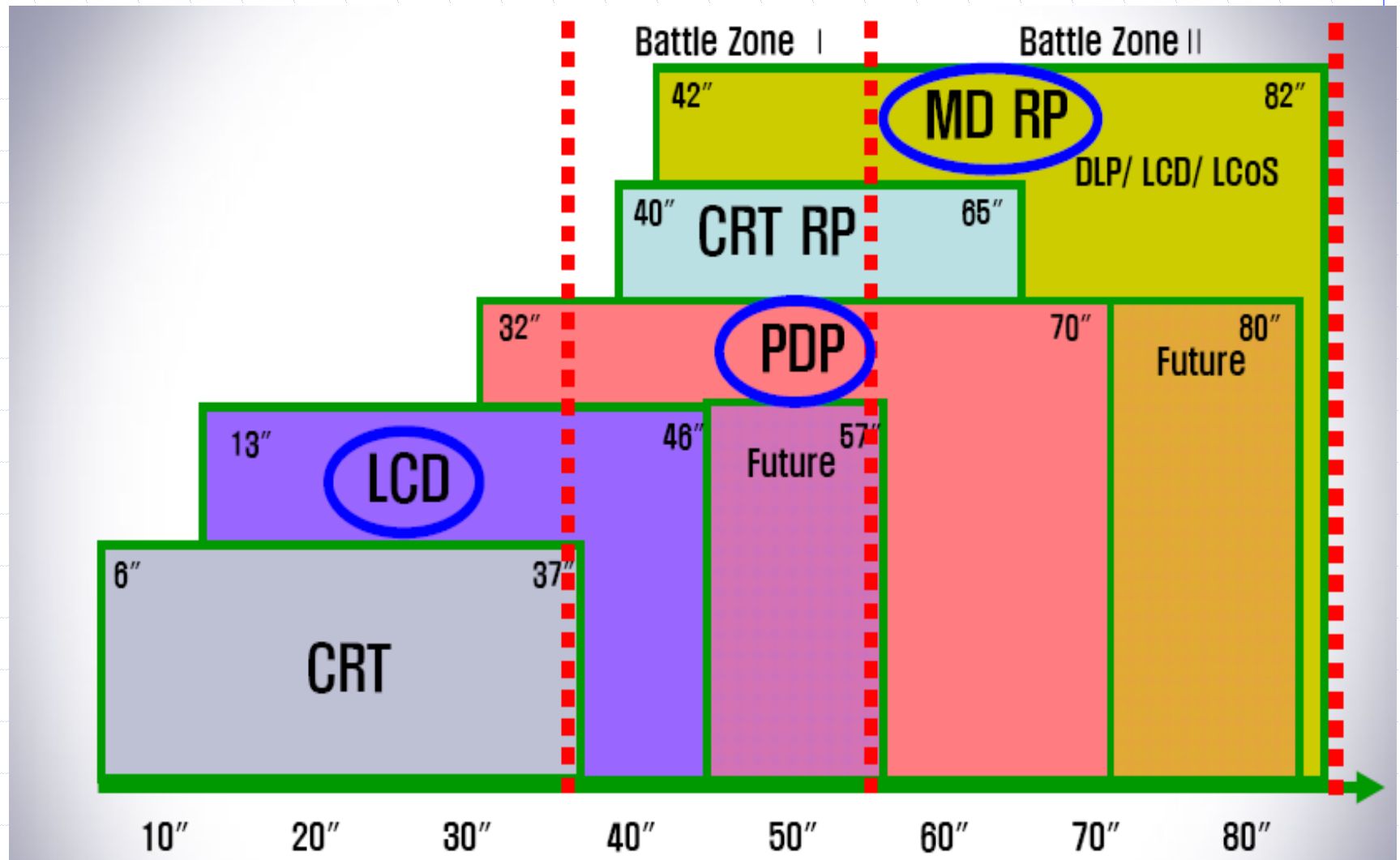
SIZE AND APPLICATION	LCD	OLED	FED	PLASMA	PROJECTION
<b>Less than 2"</b> Pager, cell phones, microdisplays	Presently occupies PM STN or LCOS	Will replace LCD	Potential exists; Cost?	Not applicable	Not applicable
<b>Between 2" and 5"</b> Industrial, Internet appliances, mobilephones, cameras/ camcorders, projectors	Presently occupied by PMSTN. AMLCD will enter as higher resolutions and speed requirements increase	Will replace LCD	Potential exists; Cost?	Not applicable	Not applicable
<b>Between 5" to 15"</b> Games, automotive, Internet applications, Instrumentation	Mainly occupied by AM LCD	Will replace LCD	Potential exists; Cost? Carbon nanotubes will succeed.	Not economical	Not applicable

# TECHNOLOGY vs APPLICATION

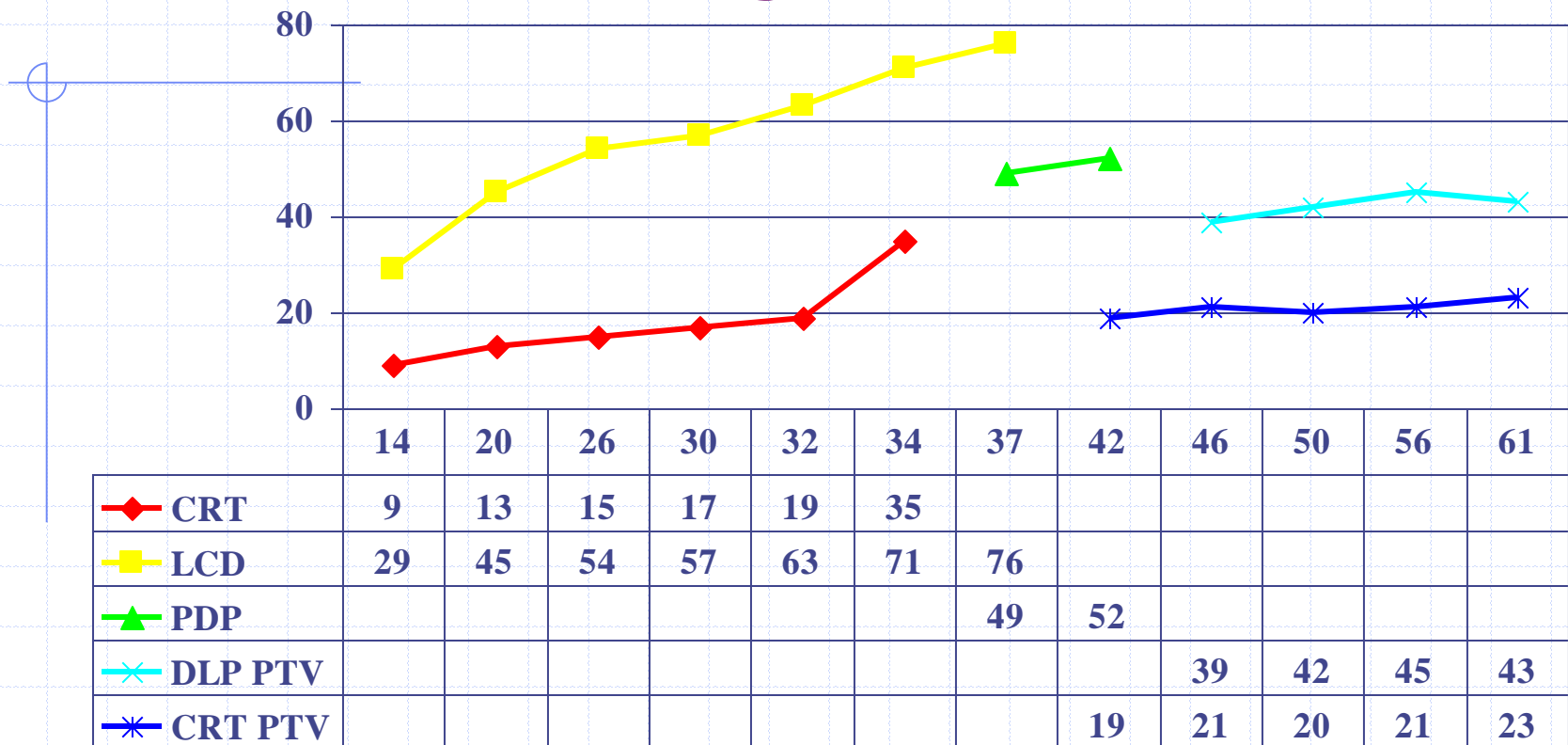
SIZE AND APPLICATION	LCD	OLED	FED	PLASMA	PROJECTION
<b>Between 15" to 20"</b> Notebook PC and Desktop	Fully occupied by AMLCD a:Si Moving to p:Si	Potential to replace LCD Sony already demonstrated 15"	Potential exists. But technology for large sizes with CNT?		
<b>Between 20" &amp; 35"</b> TV	Expensive for TV; Tiling by Rainbow is a route	Less expensive and better performance than LCD. Tiling is possible	Doubtful	High end of the size eminently suitable	Not economical
<b>Between 35" &amp; 50"</b> TV, HDTV, Large displays education and advertisement	Not applicable	No technology limitations; hopes are high	Remote possibility	Only choice	Can penetrate into PDP
<b>Above 50"</b> HDTV, Video walls				Less attractive than projection	Prime contender



# Technology Battle Zones



# Price - \$ / diagonal inch



- CRT and RPTV relatively size independent. Pricing is probably more market determined than cost determined.
- Flat panels are fairly linear with size. Costs probably rise with size and determine pricing

The background is a light blue grid. There are several blue lines and circles: a vertical line on the left, a horizontal line crossing it with a small circle at the intersection; a horizontal line near the top right; a vertical line on the far right; a horizontal line near the bottom with a small circle at its right end; and a vertical line on the right side of the bottom horizontal line.

**Thank you**